

RULE 1.26

CLAIMS

What is claimed is:

11 ~~/~~ Multicycle integration focal plane array (MIFPA), linear or area, which is a new type of electronic apparatus, and, unlike the existing FPA composed of a single-cycle integrator, is composed of

a) a correlated multicycle integrator that can be incorporated into an integrated circuit for each pixel of the MIFPA;

b) signal 10 being modulated either passively by a mechanical or electronic chopper 11 or actively by a pulsed light source 15;

c) background (and/or dark current) 14 being unmodulated;

d) the input current 17 comprising the modulated signal and unmodulated background being fed to an integrator;

e) so that the signal being accumulated while the background being cancelled;

f) so that the signal to noise ratio and dynamic range can be greatly improved.

12 ~~/~~ The method of using MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, which comprises the following steps:

— a) a lens or lens system 12 is placed between the scene or object 10 for imaging, spectroscopy, or spectroscopic imaging and the multicycle integration focal plane array (MIFPA) 13, composed of either one- or two-dimensional of photodetectors 16, where the image and or spectroscopic signal is collected;

b) a passive optical modulator 11, which can be a mechanic chopper, an electric-optical switch, a polarizer, or other devices, is placed between the scene or object 10 and the FPA 13 to modulate the photon flux from the aforesaid scene or object 10 for imaging, spectrum, or spectroscopic imaging;

c) or an active modulator, such as a pulsed light source 15, is used to generate modulated image and/or spectroscopic signals;

d) when the modulator is on in one phase ($\phi 1$ in the figure), the current generated by the detector 17 is the signal photocurrent I_s from object or scene 10, plus the DC background current I_b from the radiation 14 not modulated;

e) when the radiation from the imaging target is blocked by the modulator in another phase $\phi 2$, only the DC I_b is present;

f) by controlling the correlated multicycle integrator synchronically with the modulation control signal, using the same correlated controller 28, the integrator 30 charges the capacitor with the signal and background currents in $\phi 1$, but discharges it with background current only in $\phi 2$;

g) so that the output of 30 is accumulated signal current I_s only (plus the shot noise that is not avoidable);

h) so that the aforesaid accumulated signal current I_s can be fed to any commercial amplifier and/or display for image, spectrum, or spectral imaging using conventional imaging and/or spectroscopic methods.

13 ~~/~~ Lock-in multicycle integration focal plane array (LI-MIFPA), linear or area, which is a special type of multicycle integration focal plane array (MIFPA), linear or area, comprising:

a) all the features of claim 1;

b) with the signal accumulation phase $\phi 1$ and background cancellation phase $\phi 2$ strictly equal in time.

14 ~~/~~ The method of using LI-MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, which comprises the following steps:

a) all the steps in claim 2;

b) with the signal accumulation phase $\phi 1$ and background cancellation phase $\phi 2$ strictly equal in time.

15 *A* Gated multicycle integration focal plane array (G-FPA), linear or area, which is a special type of multicycle integration focal plane array (MIFPA), linear or area, comprising:

- a) all the features of claim 1;
- b) with ϕ_1 lasting an interval of $\alpha\tau$, ϕ_2 lasting an interval of 0 time, and a new phase ϕ_3 lasting an interval of $(1-\alpha)\tau$
- c) wherein during phase ϕ_3 the integrator 30 is turned off;
- d) wherein $\alpha \ll 1$, or $(1-\alpha)\tau \gg \tau$.

16 *B* The method of using G-MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, under the condition that the signal duty cycle α is extremely small while the background current is not extremely large, namely $\alpha \ll 1$, while I_s not $\ll I_b$, as in some types of IR fluorescence spectroscopy using nano-second pulse laser excitation, which comprises:

- a) all the steps in claim 2;
- b) with ϕ_1 lasting an interval of $\alpha\tau$, ϕ_2 lasting an interval of 0 time, and a new phase ϕ_3 lasting an interval of $(1-\alpha)\tau$
- c) wherein during phase ϕ_3 the integrator 30 is turned off;
- d) wherein $\alpha \ll 1$, or $(1-\alpha)\tau \gg \tau$.

17 *A* Gated lock-in multicycle integration focal plane array (GLI-MIFPA), linear or area, which is a special type of multicycle integration focal plane array (MIFPA), linear or area, comprising:

- a) all the features of claim 1;
- b) with ϕ_1 lasting an interval of $\alpha\tau$, ϕ_2 lasting an equal interval of $\alpha\tau$, and a new phase ϕ_3 lasting an interval of $(1-2\alpha)\tau$
- c) wherein during phase ϕ_3 the integrator 30 is turned off;
- d) wherein $\alpha \ll 1$, or $(1-2\alpha)\tau \gg \tau$.

18 88 The method of using GLI-MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, under the condition that the signal duty cycle α is extremely small and the background current is extremely large, namely $\alpha \ll 1$, and $I_s \ll I_b$, as in some types of IR fluorescence spectroscopy using nano-second pulse laser excitation, which comprises :

- a) all the steps of claim 2;
- b) with $\phi 1$ lasting an interval of $\alpha\tau$, $\phi 2$ lasting an equal interval of $\alpha\tau$, and a new phase $\phi 3$ lasting an interval of $(1 - 2\alpha)\tau$
- c) wherein during phase $\phi 3$ the integrator 30 is turned off;
- d) wherein $\alpha \ll 1$, or $(1 - 2\alpha)\tau \gg \tau$.

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CLAIMS

- 1) A new type of focal plane array — multicycle integration focal plane array (MIFPA), linear or area, which, unlike the existing FPA of single-cycle integration, utilizes three additional MOS switches (M1, M2, and M3 of fig. 1) and one additional capacitance (C1 of fig. 1) for each pixel to perform on-chip multicycle integration.
- 2) Applications of MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.
- 3) Three operational modes of MIFPA — lock-in (LI-), gated (G-), and gated lock-in (GLI-) modes.
- 4) A new type of focal plane array — lock-in multicycle integration focal plane array (LI-MIFPA), linear or area, which possesses the following features:
 - a) it uses an active or passive modulator to modulate the signal;
 - b) it does not modulate dark and/or background current;
 - c) it uses a correlated multicycle integrator for each pixel, so that the signal current is accumulated while the background and/or dark current is cancelled;
 - d) the integration time of the LI-MIFPA can be many orders longer than that of the existing FPA technology;
 - e) therefore, the signal to noise ratio, dynamic range, and low frequency or $1/f$ noise of the LI-MIFPA can be improved by many orders in comparison with the existing FPA technology.

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5) Applications of LI-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

6) A new type of focal plane array — gated multicycle integration focal plane array (G-MIFPA), linear or area, which has the same multicycle correlated integrator for each pixel as the LI-MIFPA, is programmed to operate in the gated mode, and possesses the following features:

a) it uses a pulsed light source to generate a repetitive signal (as in the case of IR fluorescence spectroscopy using nano-second pulse laser excitation);

b) the G-MIFPA is used when the number of integrated signal electrons is many orders smaller than that of the background and/or dark current electrons $\alpha I_s \ll I_b$, but αI_s is not $\ll I_b$;

c) in G-MIFPA the direction of integration of the correlated multicycle integrator does not change as in the LI-MIFPA; The integrator is turned on by a trigger signal from the gate control circuit to integrate the signal photocurrent pulse, and turned off after a certain increment of time;

d) the integration time of the G-MIFPA can be many orders longer than that of the existing FPA technology;

e) therefore, the signal to noise ratio, dynamic range, and low frequency or $1/f$ noise of the G-MIFPA can be improved by many orders in comparison with the existing FPA technology.

7) Applications of G-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

8) A new type of focal plane array — gated lock-in multicycle integration focal plane array (GLI-MIFPA), linear or area, which has the same multicycle correlated integrator for each pixel as the LI-MIFPA, is programmed to operate in the gated lock-in mode, and possesses the following features:

- a) it uses a pulsed light source to generate a repetitive signal (as in the case of LWIR spectroscopy using nano-second pulse laser excitation);
- b) the GLI-MIFPA is used when the signal is not only short, but is also associated with a much stronger background ($\alpha \ll 1; I_s \ll I_b$);
- c) in GLI-MIFPA, the correlated multicycle integrator goes through three phases (Fig. 5.b). In ϕ_1 , which lasts $\alpha\tau$, the integrator integrates both the signal pulse and strong background currents. In ϕ_2 , which has the same duration as ϕ_1 , the integrator reverses its direction of integration, and cancels the background of ϕ_1 . In ϕ_3 , which lasts much longer than ϕ_1 or ϕ_2 , the integrator is turned off.
- d) the GLI-MIFPA combines the advantage of the G-mode — reduction of the on-time of the integrator to increase the integration time — and that of the LI mode — cancellation of background to increase the integration time;
- e) therefore, the signal to noise ratio, dynamic range, and low frequency or $1/f$ noise of the G-MIFPA can be improved by many orders in comparison with the existing FPA technology.
- 9) Applications of GLI-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.
- 10) A new device — correlated multicycle integrator (comprising of one operational amplifier or source follower and four MOS switches), which can be programmed to control the MIFPA to operate in lock-in (LI-), gated (G-), or gated lock-in (GLI) mode.